MANITOBA HVDC RESEARCH CENTRE,
a Division of Manitoba Hydro International Ltd.

CIGRÉ Chile – TRV Experience

November 2017

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Presentation Outline

- History of Manitoba HVDC Research Centre
- Importance of EMT modeling for TRV investigation.
- Manitoba HVDC Research Centre's past TRV Experiences

Divisions of MHI

MANITOBA·HVDC RESEARCH CENTRE

MHRC Corporate History

1981
Established as a non-profit research organization

1993
PSCAD and RTDS **commercialize**, RTDS privatized

2000
Became a wholly-owned subsidiary of Manitoba Hydro (**for profit**)

2008
Amalgamation: became a division of Manitoba Hydro International Ltd.

2015
Scope of business includes simulation **software**, engineering **consulting**, **hardware** for power systems, and **R&D** and **laboratory** services

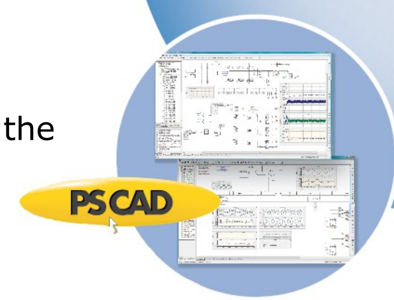
Scope of Business

Training
PSCAD and advanced power systems topics including HVDC, SVC, and FACTS

Engineering
Innovative, specialized solutions for power system community

R&D
Worldwide research partnership & long standing strategic technology alliance

Simulation Developers
Setting the standard for the transient simulation



Design & Testing
Hardware design and testing services

Simulation studies for power system operation:

- Load flow (steady state – 50/60 Hz)
- Transient stability (slow variations- electro-mechanical)
- Small signal stability (operating point)
- Fault studies
- Electromagnetic transient studies (fast transients)

Transient vs. Steady State Solutions

<u>Load Flow / Transient Stability</u>

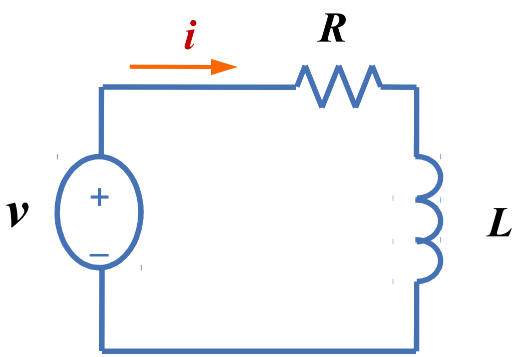
- Each solution based on phasor calculation

$$V(\omega) = (R + j\omega L) \times I(\omega)$$

<u>Electromagnetic Transients</u>

- Direct time domain solution of differential equations

$$v(t) = R \cdot i(t) + L \cdot \frac{d}{dt} i(t)$$



Transient vs. Steady State Solutions

Load Flow / Transient Stability Tools

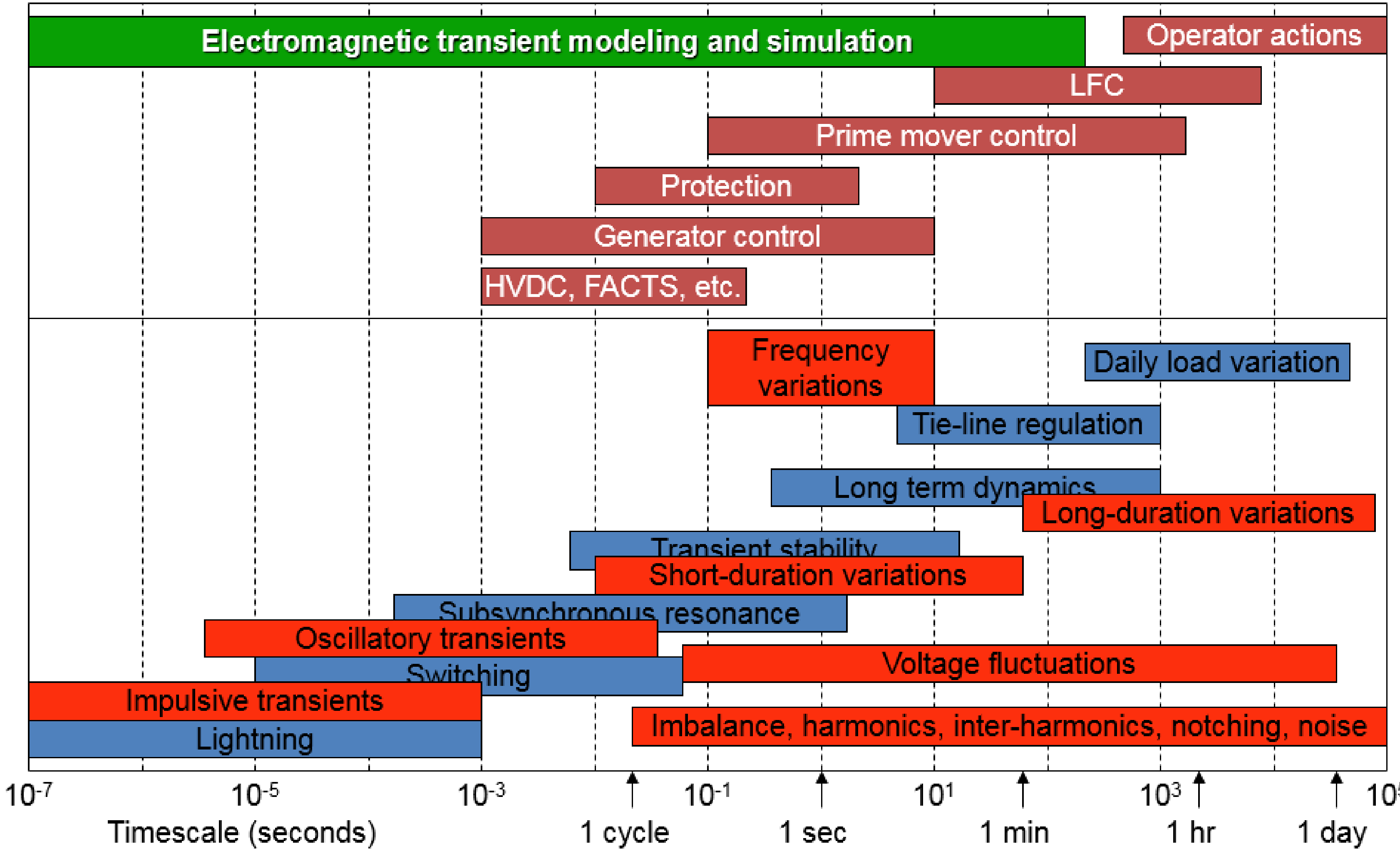
- Valid only for steady state and low frequency swings
- Simplified controls (approximated as S functions)
- Steady state equations for HVDC
- Efficient for large systems

Electromagnetic Transients Tools PSCAD

- Valid over a wide frequency range
- Detailed analog and digital controls
- Detailed switching of thyristors, diodes, GTO's
- Harmonics
- Transient over-voltages, lightning impulses
- Machine dynamics

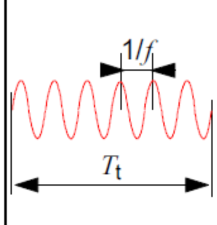
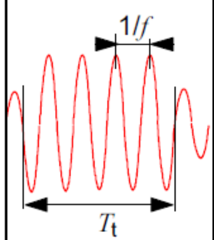
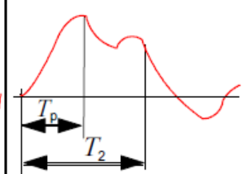
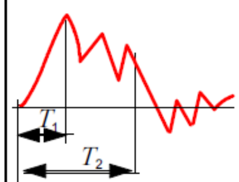
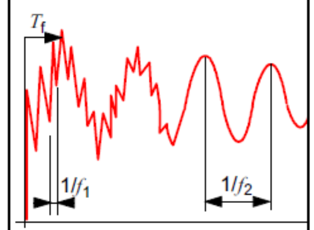
Importance of EMT modeling:

Time scales of power system phenomena



Importance of EMT modeling:

Time scales of power system phenomena

Class	Low frequency		Transient		
	Continuous	**Temporary**	**Slow-front**	**Fast-front**	**Very-fast-front**
Voltage or over-voltage shapes					
Range of voltage or over-voltage shapes	f = 50 Hz or 60 Hz $T_t \geq$ 3 600 s	10 Hz < f < 500 Hz 0,03 s $\leq T_t \leq$ 3 600 s	20 µs < $T_p \leq$ 5 000 µs $T_2 \leq$ 20 ms	0,1 µs < $T_1 \leq$ 20 µs $T_2 \leq$ 300 µs	3 ns < $T_f \leq$ 100 ns 0,3 MHz < f_1 < 100 MHz 30 kHz < f_2 < 300 kHz

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Modeling Considerations:

- TRV is a ‘fast event’ (10s of kHz)
- The impact of a transient is limited to a local area of the station
- Circuit components of the station has a major impact of TRV (bushing capacitances of equipment)
- The ‘remote system’ (1-2 buses away) generally has no impact on overall TRV response.
- It is important to represent station equipment layout/capacitances for TRV studies

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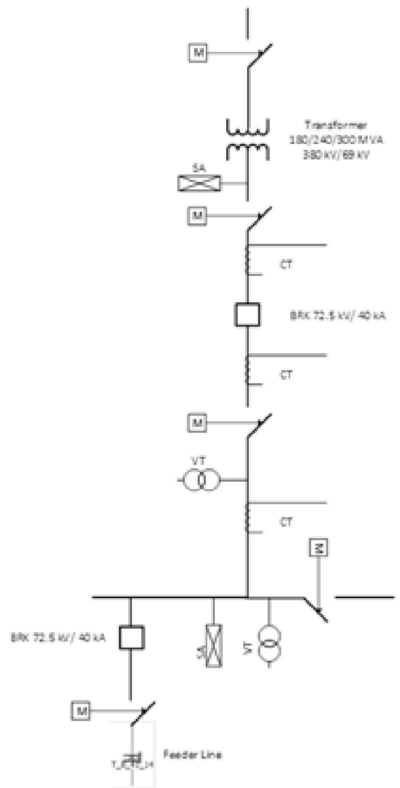
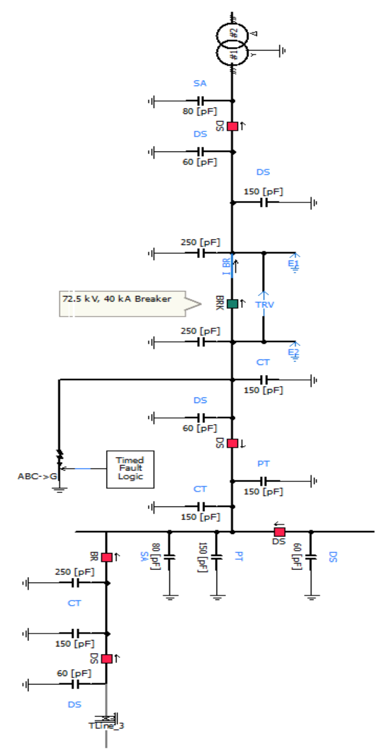
Modeling Considerations:

- Detailed station modelling



Schematic Diagram



PSCAD/EMTDC Model

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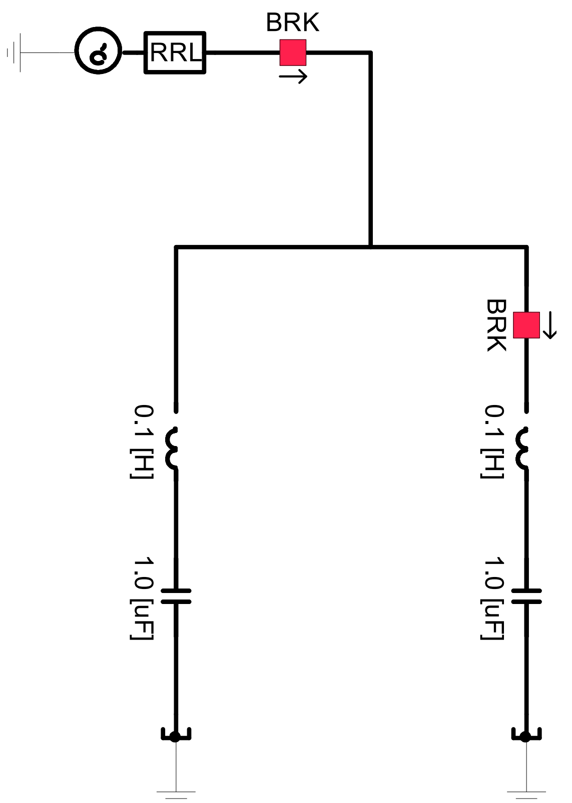
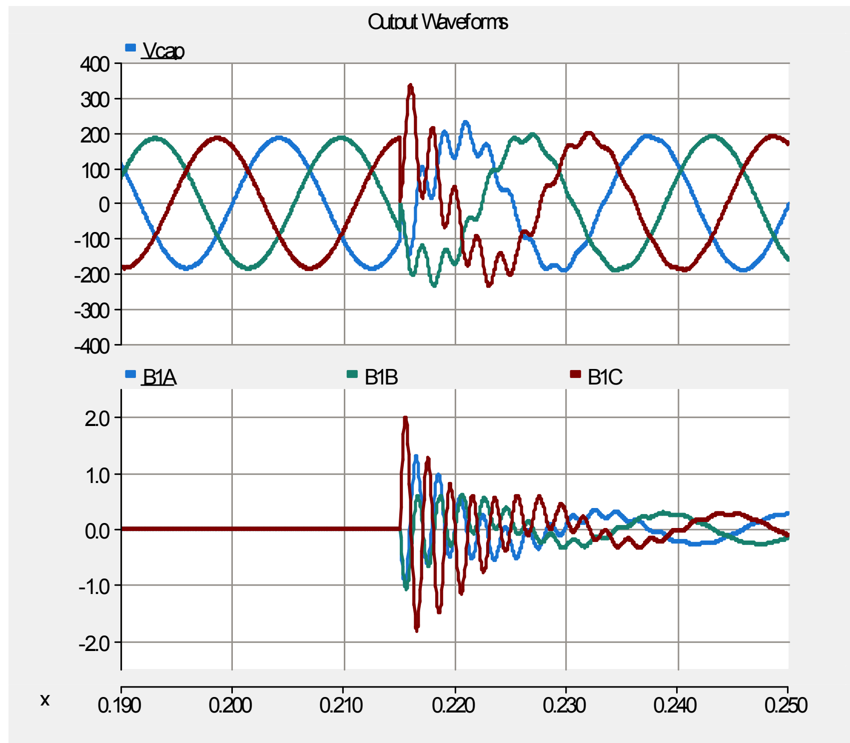
Typical Applications – Switching and Insulation Coordination

- Transmission line and equipment switching (SOV)
- Over voltages caused by lightning strikes (LOV)
- Transformer energizing –Inrush and harmonic resonance
- Capacitor bank switching
- Circuit breaker Transient Recovery Voltage (TRV)
- Temporary over voltage studies (TOV)
- Ferro resonance

A Typical Electromagnetic Transient





Engineering Services Capabilities

- MHRC offers customized and reliable solutions to assist clients during pre- and post-award stages of a project

MHRC can provide the training, tools, and assistance at any stage of your project.

- Conceptual evaluation
- Preparation of specifications and bid evaluations, as well as design review

- Engineering studies
- Factory acceptance testing support

- Construction support
- Commissioning support
- Operations and maintenance support

Past Experiences:

- Performed a significant number of TRV studies globally.
- The voltage range goes from 11 kV to 500 kV.
- TRV studies include,
  - Breakers on the overhead transmission lines.
  - Breakers on the underground/submarine cables.
  - Breakers on the generating stations.
  - Breakers on the series compensated lines.

Past Experiences:

- We have provided solutions to TRV issues for different applications, i.e.
  - Design of surge limiting capacitance
  - Surge arrester characteristic selection to mitigate peak TRV issues seen with the series compensated lines.
  - Placement of CCVTs in the station to limit the TRV rate of rise

Past Experiences:

- Selected studies include:
  - Saudi Electricity Company:
    - Over 50 TRV studies in past 5 years for 380 kV stations.
    - Breaker TRV considerations during reactor switching
    - Breaker TRV during station faults, remote faults and short line faults

Past Experiences:

- Selected studies include:
  - ENMAX – Alberta Canada:
    - Over 10 TRV studies for 11 kV to 230 kV stations.
  - Manitoba Hydro – Canada:
    - Over 10 TRV studies for 13.8 kV to 25 kV generation station.
  - Pacific Gas & Electric Company - USA
    - TRV studies for 230 kV and 500 kV lines in California, USA

Past Experiences:

- Selected studies include:
  - Red Electrica De Espana – Spain:
    - TRV studies for 345 kV series reactor.
    - Designed the TRV limiting capacitors that would be required for this installation.
  - TRV studies for over 10 wind farms in Texas USA.
  - TRV studies for a 1200 MW offshore wind farms with long ac cables in UK.

Past Experiences:

- Selected studies include:
  - TRV studies for ABB high voltage GIS substations at different locations globally – under contract with ABB Switzerland.
  - TRV studies for ALSTOM/GE high voltage substation at different locations globally.

Thank you

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